Screening Level Assessment of Variability in Exposure Estimates

Summary

MTCA defines the reasonable maximum exposure as the highest exposure that is reasonably expected to occur under current and potential future site conditions. Ecology evaluated the variability in exposure estimates by performing a screening level Monte Carlo analysis using the Crystal Ball software. This involved replacing the point estimates for several input parameters (e.g soil ingestion rate) with probability distributions for those values. The analysis indicates that the point estimate developed using a GI absorption fraction of 0.4 falls at the upper end of the simulated exposure distribution when used in combination with other MTCA exposure parameters.

Methods and Assumptions

Ecology performed a screening level assessment to evaluate whether exposure estimates produced with alternate bioavailability assumptions represent a reasonable maximum exposure. The assessment involved the following steps:

- <u>Define the equation for calculating an average daily dose of dioxin/furans that a child might receive due to incidental ingestion of contaminated soils</u>. Figure 1 identifies the equation and parameters used in this assessment. The equation represents a modified version of the equation used to calculate soil cleanup levels based on non-carcinogenic health effects.
- <u>Define the point estimates and probability distributions to be used in the assessment</u>. Ecology used the point estimates and distributions in Table 1 when preparing this assessment.
    - The calculations are based on a soil concentration of 20 ng TEQ/kg. This soil concentration has no regulatory significance and was chosen because it falls within the range of soil concentrations reported in Washington.
    - The point estimate values for soil ingestion rate, child body weight and GI absorption fraction are the default values specified in the MTCA Cleanup Regulation.
    - Ecology reviewed the scientific literature and available regulatory guidance to identify what types of distributions have been used to characterize various exposure parameters. Based on that review, Ecology selected several distributions to characterize the variability in soil ingestion rates, child body weights and the relative bioavailability of soil-bound dioxins (GI absorption fraction). The technical bases for the distributions used in this assessment are summarized in the endnotes that accompany Table 1.
- <u>Calculate the average daily dose at a soil concentration of 20 ng/kg using the point estimate values in Table 1</u>. Ecology used the point estimate values in the MTCA Cleanup Regulation to calculate an average daily dose at 20 ng TEQ/kg. Ecology also calculated average daily doses corresponding to GI absorption fractions of 0.2, 0.4, 0.6 and 0.8 (in addition to the MTCA default value of 1.0).

- Perform computer simulation (Monte Carlo Analysis) to generate simulated exposure distributions. Ecology used the Crystal Ball software.program (Version 7.2.2) to combine the point estimates and probability distributions. Ecology produced simulated exposure distributions using several different combinations of probability distributions. Ecology identified the 50th, 90th, 95th and 99th percentile values for each simulated exposure distribution.

Figure 1: Average Daily Dose

$$ADD = \frac{(TEQS*SIR*AB1*UCF_1)}{(BW*UCF_2)}$$

Where:

ADD = Average daily dose (pg/kg/day)
TEQS = Soil TEQ concentration (ng/kg)
SIR = Soil/dust ingestion rate (mg/day)
AB1 = GI Absorption fraction (unitless)
BW = Child Body Weight (kg)
UCF_1 = Unit Conversion Factor (pg/ng)
UCF_2 = Unit Conversion Factor (mg/kg)

Table 1: Point Estimates and Distributions

Parameter	Units	Point Estimate	Distribution
Soil Concentration (TEQS)	ng/kg	20	
Soil ingestion rate (SIR)	mg/day	200	
Oregon DEQ (1998) [1]			Lognormal (M = 61, SD = 67)
EPA (2001) [2]			Lognormal (M = 100; SD = 53)
EPA (2004) [3]			Lognormal (M= 61: SD = 80)
Paustenbach et al. (2006)[4]			Empirical
GI Absorption Fraction (AB1)	unitless	0.2 -1	
Paustenbach et al. (2006) [5]			Lognormal (M = 0.25; SD = 0.12; Range = 0.05 – 0.63)
Current Evaluation[6]			Triangular (0.2; 0.45; 0.7)
Child Body Weight (BW)	kg	16	
EPA (2004) [7]			Lognormal (M = 17.5; SD = 5.5)
Unit Conversion Factor (UCF_1)	pg/ng	1000	
Unit Conversion Factor (UCF_2)	mg/kg	10^6	

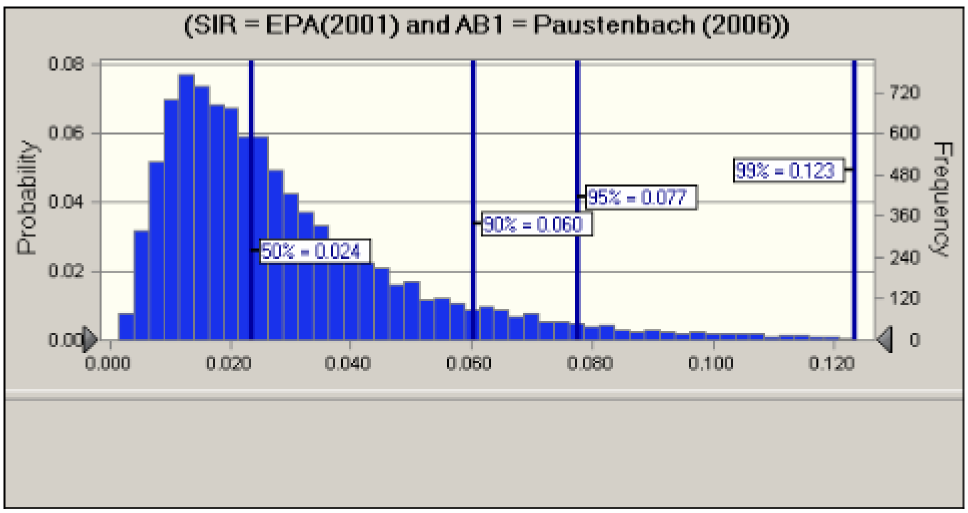
Results

The results of the probabilistic exposure assessment (based on 10,000 simulations) are summarized in Table 2. Key observations:

- The average daily dose calculated using the MTCA parameters and a GI absorption fraction of 0.4 falls at the upper end of the simulated exposure distributions. Table 2 summarizes the results of eight exposure simulations performed using different combinations of distributions for soil ingestion rate (SIR), gastrointestinal absorption fraction (AB1) and child body weight (BW).

    - The average daily dose estimate (point estimate = 0.1 pg/kg/day) calculated using the MTCA exposure parameters and an AB1 value of 0.4 generally falls in between the 90th and 95th percentile values of the simulated exposure distributions.

    - The results of exposure simulation developed using the SIR distribution from EPA (2001), the AB1 distribution from Paustenbach et al. (2006) and the BW distribution from EPA (2004) are shown in the figure below. The point estimate developed using an AB1 value of 0.4 (0.1 pg/kg/day) falls slightly above the 95th percentile of the simulated exposure distribution.



- The variability in soil ingestion rates is the most significant contributor to the variability in average daily dose calculations. Figure indicates that the variability in the soil ingestion rate contributes 43 – 85 percent of the overall variability in the simulated distribution. The variability in AB1 estimates contributes 6 to 39 percent with higher values associated with the use of the AB1 distribution from Paustenbach et al. (2006).

Table 2: Comparison of Average Daily Dose Estimates (pg/kg/day) for Dioxin Mixtures at 20 ng/kg (ppt)								
	Oregon DEQ (1998)		EPA (2001)		EPA (2004)		Paustenbach et al. (2006)	
	SIR = Lognormal (60, 67)		SIR = Lognormal (100, 53)		SIR = Lognormal (61. 80)		Empirical	
	AB1 = LN (0.25, 0.12)	AB1 = TRI (0.2, 0.45, 0.7)	AB1 = LN (0.25, 0.12)	AB1 = TRI (0.2, 0.45, 0.7)	AB1 = LN (0.25, 0.12)	AB1 = TRI (0.2, 0.45, 0.7)	AB1 = LN (0.25, 0.12)	AB1 = TRI (0.2, 0.45, 0.7)
Point Estimate (SIR = 200 mg/day; BW = 16 kg; variable GI absorption fraction)								
Bioavailability = 0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Bioavailability = 0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bioavailability = 0.6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Bioavailability = 0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Bioavailability = 1.0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Probabilistic (GI Absorption Fraction – 2 distributions; Body Weight = LN (17.5, 5.5); SIR – 4 distributions)								
50th Percentile	0.01	0.02	0.02	0.05	0.02	0.04	0.01	0.02
90th Percentile	0.05	0.07	0.06	0.1	0.07	0.13	0.03	0.04
95th Percentile	0.09	0.1	0.08	0.13	0.1	0.18	0.04	0.06
99th Percentile	0.24	0.17	0.12	0.2	0.19	0.34	0.06	0.08
Percentile for 0.4 Point Estimate	@95th	@95th	@95th	@90th	@ 95th	@85th	> 99th	> 99th
Contribution to Variance								
Soil Ingestion Rate	75	85	47	63	72	83	43	67
GI Absorption Fraction	17	6	36	14	20	6	39	13
Child Body Weight	8	9	17	23	8	11	18	20

Endnotes

[1] *Oregon Department of Environmental Quality. 1998. Guidance for Use of Probabilistic Analysis in Human Health Risk Assessments. Waste Management and Cleanup Division, Portland OR. January 1998 (Updated November 1998).* The Oregon DEQ guidance that risk assessors use a lognormal distribution (mean = 60, standard deviation = 67; range 0.5 to 400) to characterize the variability in soil ingestion rates for children.

[2] *Environmental Protection Agency. 2001. Baseline Human Health Risk Assessment Vasquez Boulevard and I-70 Superfund Site, Denver CO. EPA Region VIII (August 2001, Reissued December 2001).* EPA Region VIII used several approaches to characterizing the soil/dust ingestion rates as part of the risk assessment for the Vasquez Boulevard/I-70 site outside Denver CO. One approach involved fitting a lognormal distribution to the EPA guidance values of 100 mg/day and 200 mg/day for CTE and RME exposures.

[3] *Environmental Protection Agency. 2004. A Probabilistic Exposure Assessment for Children Who Contact CCA-Treated Playsets and Decks: Using the Stochastic Human Exposure and Dose Simulation Model for the Wood Preservative Scenario (SHEDS-Wood).* EPA used a lognormal distribution (mean = 60.6, standard deviation = 80.5) to characterize the variability in soil ingestion rates [Table 49]. The distribution was based on a reanalysis of data from the Calabrese et al. (1989).

[4] *Paustenbach, D.J., K. Fehling, P. Scott, M. Harris, and B.D. Kerger. 2006. Identifying Soil Cleanup Criteria for Dioxins in Urban Residential Soils: How Have 20 Years of Research and Risk Experience Affected the Analysis? Journal of Toxicology and Environmental Health Part B, 9:87-145.* Paustenbach et. al. (2006) reviewed the scientific evidence and methodologies that have been used to assess the risks of dioxin-contaminated soils and presented the results of a probabilistic risk assessment. The authors used an empirical distribution to characterize the variability in soil ingestion rates. The distribution had the following characteristics: 25^{th} percentile = 11 mg/day; 50%tile = 24 mg/day; 75%tile = 41 mg/day; 90%tile = 73 mg/day; 95^{th}tile = 88 mg/day; and maximum = 137 mg/day. [Table 9]

[5] *Paustenbach, D.J., K. Fehling, P. Scott, M. Harris, and B.D. Kerger. 2006. Identifying Soil Cleanup Criteria for Dioxins in Urban Residential Soils: How Have 20 Years of Research and Risk Experience Affected the Analysis? Journal of Toxicology and Environmental Health Part B, 9:87-145.* Paustenbach et. al. (2006) reviewed the scientific evidence and methodologies that have been used to assess the risks of dioxin-contaminated soils and presented the results of a probabilistic risk assessment. The authors used a lognormal distribution (mean = 0.25, standard deviation = 0.12 and range of 0.005 to 0.63) [Table 9].

[6] Ecology compiled the results of studies performed to evaluate the bioavailability of soil-bound dioxins. Ecology used the results from the studies using liver content as the study endpoint to construct a triangular distribution (0.2, 0.45, 0.7).

[7] *Environmental Protection Agency. 2004. A Probabilistic Exposure Assessment for Children Who Contact CCA-Treated Playsets and Decks: Using the Stochastic Human Exposure and Dose Simulation Model for the Wood Preservative Scenario (SHEDS-Wood).* EPA used a lognormal distribution (mean = 17.5, standard deviation = 5.5) to characterize the variability in child body weights [Table 49]. The distribution was based on a analysis of the NHANES III data for children ages 1-6 years of age.